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During the autumn of 1952 the owners of the Taylor & Son's Orchard at Clyde in northern Ohio noted that mites, *Metatetranychus ulmi*, were more abundant than usual. The section of the orchard in which this was most obvious was composed largely of trees of the variety Red Delicious and had been sprayed for several years with parathion.[1] From two to four applications of this material had been made each season with dosages varying from ½ to 1½ pounds of a 15% wettable powder per 100 gallons.

Despite the increased number of mites little thought was given to this situation and the first and second insecticidal sprays in 1953 consisted of parathion applied in the petal-fall and in the first cover spray. Shortly thereafter numerous living mites were noted on the foliage and a third spray of parathion was made. This likewise failed to control and the writer was consulted as to the cause and possible remedies for the condition. As other orchardists in Ohio were having difficulty in controlling mites with parathion and as reports from other states regarding the same condition had been received, this case was tentatively diagnosed as one of resistance. The grower was thereafter advised that a miticide of an entirely different chemical nature be used to control the

[1]For the sake of brevity many of the miticides used in this study are referred to by their trade names or numerical designations. The following list gives the chemical names of all materials so listed. Approved "coined" chemical names are not included.
Aramite, 2 (p-tert'-butylphenoxy) isopropyl 2-chloroethyl sulfite.
Chlorobenzilate, 2 hydroxy-2, 2 bis (4-chlorophenyl) ethyl acetate.
Diazinon, O, O-diethyl-O (2 isopropyl-4-Methyl-pyrimidyl) 6 thiophosphate.
Dimite, 25% EC, Di (P-Chlorophenyl) Methyl-Carbinol.
EPN, 27% WP, Ethyl p-nitrophenyl thionobenzenephosphonate.
Meta-systox, O, O-dimethyl O-2-ethylmercaptoethyl thiophosphate.
Strobane, a terpene polychlorinate.
A. C. 528, 25% WP, 2, 3-dioxanedithiol-S-bis-(O, O-diethylphosphorodithioate). Supplied by Hercules Powder Company (1955).
F.W. 293, 25% WP, 1, 1-bis (chlorophenyl) trichloroethanol. Supplied by Rohm & Haas Company (1955).
R-1303, 25% WP, Supplied by Stauffer Chemical Company (1955).
7744, 50% WP, N-Methyl alpha naphthyl urethane. Supplied by Carbide & Carbon Chemical Corporation (1955).
908, 25% WP, A copper complex of an organic dithiophosphate. Supplied by Niagara Chemical Division, F. M. & C. Corporation (1955).

infestation. Aramite was selected and two consecutive applications of this material gave good commercial control during the remainder of the growing season. Aside from the Aramite treated sections of the orchard, two blocks of trees were sprayed with other materials. In one the parathion schedule was continued for two more applications, and in the other EPN was likewise applied. Parathion was used at the rate of 2 pounds of 15% WP per 100 gallons and EPN at ½ pound of 27½ WP per 100. Final counts made on 12 trees of each block on July 31 are summarized as follows:

Materials Used	Mites per Leaf
Aramite schedule	.1
EPN schedule	1.3
Parathion schedule	23.0

The difference in population and also in the amount of mite injury on the parathion sprayed block as compared with the other sprayed blocks was quite definite. The differences between the EPN and the Aramite sprayed blocks are not significant but the population on the EPN section was higher than is normally expected with such a spray schedule. The indications were that the parathion resistance had also effected the action of EPN.

During the season of 1954 full scale field experiments were conducted in the same orchard but in the block that had been treated with Aramite during the previous summer. The object of these experiments was twofold: First, to determine if the use of the non-phosphorus miticide Aramite in 1953 had lessened the degree of resistance to parathion; second, to test the efficiency of other miticides against the mite population, which was presumably still resistant. Single tree plots replicated four times in randomized blocks were used. No early season miticides were employed.

The first experiment was started in early June when plot trees were selected and sprayed. Two spray applications were made using a standard hydraulic sprayer carrying 600 pounds of pressure. The spray dates were June 1 and June 10. The materials, the amounts per 100 gallons, and the results in terms of mites per leaf are summarized and shown in table 1.

During the course of the experiment six different counts were made. These as shown in table 1 illustrate the development and the amount of infestation for each treatment. In general, good commercial control was secured by all materials to July 14, when treatments 5, 8, and 10 were found heavily infested. As noted in the table, treatment 5 was sprayed with Strobane WP, treatment 8 with Glyodin (Crag Fungi-

TABLE 1.—First Experiment Against Parathion Resistant Mites. Clyde, Ohio, 1954

Treatment No.	Material	Amount per 100 gals. applied on June 1	Amount per 100 gals. applied on June 10	Mites per Leaf: June 15	June 21	July 1	July 14	July 22	July 30
1	Aramite 15 % WP	1 ½ lbs.	1 ½ lbs.	0	0	0	.5	1.0	7.6
2	Aramite Exp. 15 % WP	1 ½ lbs.	1 ½ lbs.	0	T	T	.7	1.3	11.5
3	Aramite Exp. 15 % WP	¾ lb.	¾ lb.	0	0	0	2.0	1.0	16.4
4	Ovex 50 % WP	½ lb.	½ lb.	T*	0	0	1.0	.5	7.3
5	Strobane 50 % WP	2 lbs.	2 lbs.	T	.6	.4	12.5	—	——
6	Strobane 72 % EC	1 pt.	1 pt.	0	0	T	.9	1.4	10.1
7	Dimite	1 pt.	1 pt.	0	0	.1	1.0	1.0	10.5
8	Glyodin (Crag Fungicide)	1 qt.	1 qt.	.7	1.6	3.6	32.0	—	——
9	EPN 27 % WP	½ lb.	½ lb.	0	0	T	.9	.6	10.0
10	Parathion 15 % WP	1 ½ lbs.	1 ½ lbs.	.4	.6	1.4	20.0	—	——

*T = Trace or less than .1 mite per leaf.

cide), and treatment 10 with parathion. It is quite evident that these three treatments were inferior and that mites were still resistant to parathion. This being the case, the three treatments were withdrawn from the experiment and sprayed with other materials. The remaining treatments continued without spraying to July 30 when all of them were found infested to the extent that retreatment was necessary. There were no significant differences in control between the seven remaining treatments, all having given control to this date.

The second experiment started with the spraying of treatments 5, 8, and 10 on July 19, and the respraying of all other plots on August 4. The schedule and results are shown in table 2.

TABLE 2.—Second Experiment. Clyde, Ohio, 1954

Treatment No.	Material	Amount per 100 gals. applied on July 19	Amount per 100 gals. applied on August 4	Mites per Leaf July 14*	July 22	July 30	August 9
1	Aramite 15% WP	———	1½ lbs.	——	—	7.6	1.1
2	Aramite Exp. 15% WP	———	1½ lbs.	——	—	11.5	1.5
3	Aramite Exp. 15% WP	———	¾ lb.	——	—	16.4	.7
4	Ovex 50% WP	———	½ lb.	——	—	7.3	.8
5	Strobane 50% WP	2 lbs.	———	12.5	8.9	34.5	——
	Demeton 22% EC	———	4 ozs.	——	—	——	.6
6	Strobane 72% EC	———	1 pt.	——	—	10.1	4.5
7	Dimite 25% EC	———	1 pt.	——	—	10.5	.8
8	Demeton 22% EC	2 ozs.	2 ozs.	32.0	1.4	6.1	.0
9	EPN 27% WP	———	½ lb.	——	—	10.0	.5
10	Meta-Systox EC	3 ozs.	3 ozs.	20.0	.5	3.4	.0

*Pre-spray count.

The result on treatment 5 which was resprayed with Strobane WP on July 19 was very poor. This formulation of the material was not nearly as effective as the Strobane EC used on treatment 6. However, the emulsifiable concentration gave enough foliage injury to prohibit its recommendation. Due to failure to control, Strobane was replaced by demeton (Systox) in the spraying of treatment 5 on August 4. Treatment 8 was sprayed with demeton, 22% EC at 2 ounces per 100 gallons, on July 19 and on August 4. The excellent results with this low dosage show that mites were not resistant to this material. The same result was also secured for treatment 10 where Meta-Systox replaced parathion as the miticide. All other treatments were reasonably effective as shown by the count of August 9. Unfortunately a mistake by one of

the orchard spraymen on August 11 caused a miticidal application to be made on a number of the experimental trees. Several counts were made following this but due to doubt caused by this mistake the data are not included in the table. However, excellent control on treatments 5, 8, and 10 was noted to the end of the season. Other treatments gave good commercial control but the number of mites was somewhat greater.

In 1955 experiments were conducted in the same orchard. Numerous trees in this section had not received any phosphorus based spray since the spring of 1953. Trees such as these were used for the plots treated with parathion. Again no early season miticide was employed. All plots were sprayed on June 2 and again on June 14. The schedule and results are shown in table 3.

There was some early season injury to the foliage of Red Delicious sprayed with chlorthion and the miticide on this treatment (No. 7) was changed. Treatment 7 data are therefore not included in the table. Outstanding, all season control was obtained by the use of Rohm & Haas F.W. 293 and with demeton. Populations on the F.W. 293 trees were kept at especially low levels. Parathion (treatment 10) and Diazinon (treatment 8) gave control up to mid August and all other materials to August 1. The results with parathion would indicate that mites had lost a considerable part of their resistance after two years' use of another miticide.

The second experiment of the year was made on a block of Red Delicious trees adjacent to those already in use. (See table 3). In addition to the non-phosphorus miticide that was used in 1953, this new block had received an oil spray in the delayed dormant periods of both 1954 and 1955. Thus, the mite population had had no contact with parathion or related compounds for a period of some 25 months. As it was desired to test materials to which mites had developed resistance in this or other orchards, parathion, malathion, and EPN were included in this schedule. Demeton, ovex, and F.W. 293 were also used. The complete schedule and results are given in table 4.

Despite the use of an early season oil spray a heavy mite population developed on these trees in early July. The experimental sprays were applied on July 6 and again on July 18. The 12-day interval between sprays was caused by the press of other work and is too long for good control by most of the phosphorus based sprays. For this reason we have good immediate control with parathion, malathion, etc., but little residual. This has always characterized the use of parathion even with non-resistant populations. Therefore, while the first impression is that the mites are still resistant to parathion, etc., there is still some doubt as

TABLE 3.—First Experiment. Clyde, Ohio, 1955

Treatment No.	Material	Amount per 100 gals. applied on June 2	Amount per 100 gals. applied on June 14	Mites per Leaf										
				June			July		August				Sept.	
				2*	16	27	12	22	4	10	19	30	7	21
1	Aramite 15% WP	1½ lbs.	1½ lbs.	5.0	.2	.1	.4	.7	3.1	—	—	—	—	—
2	Ovex 50% WP	½ lb.	½ lb.	5.0	0	0	.3	.2	1.8	—	—	—	—	—
3	Chlorobenzilate 25% WP	1 lb.	1 lb.	5.0	0	.5	.2	.8	2.5	—	—	—	—	—
4	Niagara 908 25% WP	3 lbs.	3 lbs.	5.0	0	.1	0	.2	2.1	—	—	—	—	—
5	F.W. 293 25% WP	1 lb.	1 lb.	5.0	0	.1	.1	0	.1	0	.8	.4	1.2	1.5
6	Hercules AC 528 25% WP	1½ lbs.	1½ lbs.	5.0	0	.1	.1	.1	2.9	—	—	—	—	—
8	Diazinon 25% WP	2 lbs.	2 lbs.	5.0	0	0	.3	.2	.6	1.8	6.3	—	—	—
9	Demeton 22% EC	4 ozs.	4 ozs.	5.0	0	0	0	.1	.2	.1	1.4	4.2	3.7	7.8
10	Parathion 15% WP	1½ lbs.	1½ lbs.	5.0	.1	.1	.5	0	.8	1.3	9.4	—	—	—

*Pre-spray count.

TABLE 4.—Second Experiment. Clyde, Ohio, 1955

Treatment No.	Material	Amount per 100 gals. applied on July 6	Amount per 100 gals. applied on July 18	Mites per Leaf: July	July				August			Sept.
				6*	12	18	22	29	10	19	30	16
1	Parathion 15% WP	½ lb.	½ lb.	31.0	.8	7.8	0	6.8	3.5	3.3	——	——
2	Parathion 15% WP	1½ lbs.	1½ lbs.	31.0	.7	5.9	.1	1.8	1.5	1.1	18.1	——
3	EPN 27% WP	¼ lb.	¼ lb.	31 0	T	1.7	0	.2	.1	1.1	18.8	——
4	EPN 27% WP	½ lb.	½ lb.	31.0	.5	1.7	0	T	.1	1.6	8 5	——
5	Malathion 25% WP	3 lbs.	3 lbs.	31.0	1.9	7.1	0	6.1	.6	5.4	25.9	——
6	Demeton 22% EC	2 ozs.	2 ozs.	31.0	T	.4	0	.1	T	.1	2.1	——
7	Demeton 22% EC	4 ozs.	4 ozs.	31.0	0	.2	0	0	0	.2	.8	——
8	Demeton 22% EC	4 ozs.	—	31.0	T	.7	0	.5	.2	1 8	11.5	——
9	F.W. 293 25% WP	1 lb.	1 lb.	31.0	0	1.0	0	0	0	.1	T	.1
10	Ovex 50% WP	½ lb.	½ lb.	31.0	0	.1	0	0	0	.2	3.9	4.5

*Pre-spray count.

T = Trace or less than .1 mite per leaf.

to this fact. A comparison of treatments 1 to 5 inclusive with treatments 6 and 7 is of interest since mites have not developed a resistance to demeton. The results show much better results with demeton and might be interpreted as the retention of resistance to parathion by the mites.

The superior results obtained when two sprays of demeton were used at low dosage, in comparison with a single spray of double the amount, are quite definite. Excellent results were again obtained with F.W. 293 and good control with ovex.

In late August a further test of the effectiveness of parathion against this mite population was made. Most of the trees used in this test had previously received parathion or other related compounds earlier in the season. Therefore, the mites on these trees had had some recent contact with the test materials. The results are given in table 5.

An inspection of this table shows that one application of parathion at either ½ pound per 100 gallons or 1½ pounds per 100 was not effective. When two applications were made with an interval of only 6 days between sprays much better results were secured especially with the 1½ pound dosage. Some natural decline on all these plots was noted due to the approaching end of the season but all of the plots showed increases in population at the time of the last two counts. Some further comparisons should also be made. For example, the performance of treatments 9 and 10 in table 4 is practically equal to that of treatment 4 in table 5 despite the fact that treatment 4 had had two more spray applications. It has already been noted that the trees used for the work presented in table 5 had also received phosphorus based sprays earlier in the season. Adjacent to these trees were some that had had no contact with parathion for about 27 months. One of these trees was sprayed with the same schedule that treatment 4, table 5 received. The results were much better than those on treatment 4 indicating that the extra parathion sprays had increased resistance. As the data from the extra trees are unsupported due to the lack of replicates, the result is not definite. However, the circumstances of the experiment make it highly probable.

One other experiment in this orchard should be reported. In table 3 it was noted that following the count of August 4 several treatments were withdrawn from the experiment and sprayed according to the schedule in table 6. Only one spray application was made, this being on August 4 following the counting of the treatments.

TABLE 5.—Third Experiment. Clyde, Ohio, 1955

Treatment No.	Material	Amount per 100 gals. applied on Aug. 24	Amount per 100 gals. applied on Aug. 30	Mites per Leaf: August 24*	August 30	September 7	September 16	September 21	September 30	Oct. 21
1	Parathion 15% WP	½ lb.	0 lbs.	2.3	14.2	19.4	4.9	7.1	9.6	6.5
2	Parathion 15% WP	½ lb.	½ lb.	9.0	8.1	1.8	1.0	1.1	3.9	6.5
3	Parathion 15% WP	1 ½ lbs.	0 lbs.	6.1	3.3	7.9	2.5	2.9	10.5	1.7
4	Parathion 15% WP	1 ½ lbs.	1 ½ lbs.	5.4	9.4	.3	.4	.4	.5	1.7
5	Check, No Treatment	0 lbs.	0 lbs.	6.9	25.9	22.9	3.9	4.7	5.9	2.0

*Pre-spray count.

TABLE 6.—Fourth Experiment. Clyde, Ohio, 1955

Treatment No.	Material	Amount per 100 gals. applied on August 4	Mites per Leaf				
			August				Sept.
			4*	10	19	30	7
1	Stauffer R-1303 WP	1 lb.	3.1	0	0	.7	.4
2	Ovex 50% WP	½ lb.	1.8	0	.3	1.6	1.7
3	Chlorobenzilate 25% WP	1 lb.	2.5	0	1.6	4.3	6.0
4	Niagara 908 25% WP	4 lbs.	2.1	.3	2.4	13.7	12.3
6	C. & C. 7744 50% WP	2 lbs.	2.9	.2	2.1	20.3	15.7

*Pre-spray count.

Excellent control for the remainder of the season was secured with Stauffer R-1303 and good control with ovex. Chlorobenzilate gave commercial control while Niagara 908 and Carbide & Carbon 7744 were not satisfactory.

SUMMARY AND CONCLUSIONS

Experiments continued over a three year period in an orchard where a population of *Metatetranychus ulmi* was definitely resistant to parathion produced the following results:

1. The cessation of parathion usage for one season did not reduce resistance to that material.
2. The cessation of parathion usage for two years permitted the reemployment of parathion with good results. This indicated that resistance was definitely reduced.
3. Following several applications of parathion, mites appear to recover resistance rapidly. This applies especially when low dosages are used.
4. Parathion resistant mites were easily controlled by demeton and related systemics.
5. Present day non-phosphorus miticides, such as ovex, Aramite, Dimite, Chlorobenzilate, etc., gave adequate control of this resistant population.
6. Among the new miticides, Rohm & Haas F.W. 293, Stauffer R-1303 and Hercules AC 528 appear very promising.